Experimental and Applied Acarology **28:** 289–296, 2002.

Control of *Ixodes scapularis* and *Amblyomma americanum* through use of the '4-poster' treatment device on deer in Maryland

JOHN F. CARROLL[1,*], PATRICIA C. ALLEN[1], DOLORES E. HILL[1], J. MATHEWS POUND[2], J. ALLEN MILLER[2] and JOHN E. GEORGE[2]
[1]*Parasite Biology, Epidemiology and Systematics Laboratory, ARS, USDA, BARC-East, Building 1040, Beltsville, MD 20705, USA*
[2]*Knipling-Bushland US Livestock Insects Research Laboratory, ARS, USDA, Kerrville, TX, USA*

Abstract. Deer self-treatment devices ('4-posters') were evaluated for their efficacy in reducing populations of blacklegged ticks, *Ixodes scapularis*, and lone star ticks, *Amblyomma americanum*. At each of three locations in Maryland, 25 '4-posters' were operated in study areas of approximately 5.18 km^2. Populations of host-seeking ticks were monitored by flagging of treated areas and similar untreated control areas without '4-posters.' From 1998 to 2002 the percent mortalities achieved were 69, 75.8 and 80 at the three study sites infested with *I. scapularis* nymphs, and 99.5 and 95.3 for *A. americanum* nymphs at the two sites where this species occurred.

Key words: *Ixodes scapularis*, *Amblyomma americanum*, deer, bait, amitraz

Introduction

In the northeastern and mid-Atlantic states of the US, populations of the blacklegged tick, *Ixodes scapularis* Say, the principal vector of the agent causing Lyme disease, are embedded in a mosaic of suburban home sites, forests and even urban parks. Controlling populations of three-host ticks, such as *I. scapularis*, that feed on a variety of vertebrate hosts has historically been difficult. Area wide applications of acaricides against *I. scapularis* in wooded suburban habitats are challenging and encumbered by environmental side effects. Although *I. scapularis* and lone star ticks, *Amblyomma americanum* (L.) will feed on a wide variety of hosts (e.g., raccoon, gray squirrel, skunk) (Fish and Dowler, 1989), adult *I. scapularis* and all feeding stages of *A. americanum* feed primarily on white-tailed deer, *Odocoileus virginianus*

*Author for correspondence (E-mail: jcarroll@anri.barc.usda.gov)

(Zimmermann) (Wilson *et al*., 1985; Bloemer *et al*., 1988). Reductions in white-tailed deer populations have been shown to be followed by declines in numbers of *I. scapularis* (Wilson *et al*., 1988). A technology that would kill the ticks on white-tailed deer would not only cause a decrease in tick populations, but because the deer are still present they would continue acquiring and killing ticks producing further reductions in tick numbers.

Devices that treat large mammals with an acaricide as they access baits, have been developed by Duncan and Monks (1992), Sonenshine *et al*. (1996) and Liegner (1991). With the Duncan and Monks (1992) and Sonenshine *et al*. (1996) devices, animals acquire acaricide by rubbing against a treatment column as they feed, whereas with the Liegner (1991) device deer are sprayed with an acaricide as they lick a salt block.

The '4-poster' deer self-treatment device developed at the USDA, ARS, Knipling-Bushland US Livestock Insects Research Laboratory, Kerrville, Texas passively applies acaricide to deer as they rub against paint rollers while feeding on whole kernel corn bait (Pound *et al*., 2000a). Nearly 90% of adult *I. scapularis* attach to the head, ears, neck and brisket of white-tailed deer (Watson and Anderson, 1976; Schmidtmann *et al*., 1998). Bloemer *et al*. (1988) reported that 66.6–73.3% of adult female *A. americanum* attached to white-tailed deer were on the head, ears and neck, as were >92% of attached larvae and nymphs. The '4-poster' proved to be effective in controlling *A. americanum*, when tested with white-tailed deer in fenced areas in Texas (Pound *et al*., 2000b).

As part of a large-scale project to assess the efficacy of the '4-poster' technology against *I. scapularis* in five states in the northeastern US, '4-posters' were evaluated at three locations in Maryland. This paper focuses on the impact of the '4-poster' technology on nymphal populations of *I. scapularis* and *A. americanum*.

Materials and Methods

A treatment area of approximately 5.18 km^2 was established at each of three locations, Loch Raven in Baltimore County, Beltsville Agricultural Research Center (BARC) in Prince George's County, Gibson Island in Anne Arundel County. A control area similar in size, habitats, land use and deer and tick numbers was chosen $\geq$3.2 km from its paired treatment area. According to Marchinton and Hirth (1984), white-tailed deer rarely leave their home ranges, which often do not exceed a radius of 1.6 km. To avoid movement of deer between treatment and control areas, paired treatment and control sites were separated by approximately 9 km or bodies of water that would require a deer to swim 0.5–1.0 km to cross them. Each treatment and control site was required to have populations of ≥20 white-tailed deer per 259 ha and moderate or dense population of *I. scapularis*. There was no legal hunting at the Loch Raven site, but managed deer hunting occurred at BARC and Gibson Island. At each treatment site 25 '4-posters' were placed in locations where deer activity or signs of activity were the greatest.

In each '4-poster' device, a central bin held 120 kg of cleaned whole corn, which flowed by gravity into two feeding troughs (one at either end of the device). When deer fed at the trough, they rubbed against paint rollers impregnated with an oily pour-on formulation of 2% amitaz (Point-Guard®, Hoechst-Roussel, Somerville, NJ). The paint rollers were held upright on PVC posts, two at each end of the '4-poster,' hence its name. Corn consumption was monitored by calibrated markings inside the corn bin. Amitraz was applied at the rate of 40 ml per roller per week on devices that had ≤43 kg of corn consumed from them weekly. A second application of amitraz was made to '4-posters' from which >43 kg corn were consumed per week. At Loch Raven the devices were operated from October through December and from the end of February or beginning of March, depending on the weather, until June. At Gibson Island and BARC, operation of the '4-posters' continued through the summer, because of the presence at those sites of *A. americanum*, the larvae and nymphs of which feed in large numbers on deer.

Populations of host-seeking *I. scapularis* at the three sites, and *A. americanum* at BARC and Gibson Island were sampled by flagging with a 0.5 by 0.5 m flannel cloth at 15 sites at each treatment and control area (Figure 1). Sampling sites were chosen on the basis of the presence of ticks, because the purpose of the study was to ascertain the effectiveness of '4-poster' in reducing the numbers of ticks. Leaf litter and low growing vegetation were flagged while walking slowly for 30 s (≈10 m). Ten such samples were taken at each of the 15 locations per site. Nymphs were counted and released in the ≈10 m transect just flagged. Each year nymphs of both *I. scapularis* and

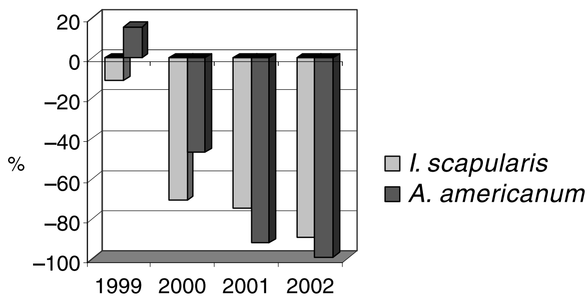

Figure 1. Percent change in numbers of host-seeking nymphs captured by flagging in treatment areas from 1998 totals.

A. americanum, and adult *A. americanum* were sampled on three or four (Loch Raven) dates in May and June. Comparisons between numbers of nymphs at treatment and control areas were made using Student's *t* test.

Results

Numbers of host-seeking *I. scapularis* nymphs that were captured by flagging in 1998, during the first year of the study, were greater in the BARC and Gibson Island treatment areas than in the paired control areas; at Loch Raven the control area was more populous than the treatment area ($P = 0.005$, Table 1). Notably, in 2000 (the first year a large impact of the treatment on nymphal populations could be expected to occur) numbers of nymphs in treatment areas dropped dramatically from the previous years, whereas the control populations did not show such declines (Table 1). From 2000 to 2002, the numbers of *I. scapularis* nymphs in all treatment areas declined each year, except for 2001 at Loch Raven. By 2002, at BARC and Gibson Island

Table 1. Average number of *I. scapularis* and *A. americanum* nymphs captured by flagging at 15 locations on three or four dates at each treatment and control site

	1998	1999	2000	2001	2002
I. scapularis					
Loch Raven[a]					
Treatment	282.5 ± 38.0	210.3 ± 38.5	71.0 ± 19.7	99.3 ± 13.8	52.8 ± 7.8
Control	383.8 ± 10.5	476.5 ± 44.2	327.8 ± 61.4	468.3 ± 40.1	231.5 ± 15.5
BARC					
Treatment	235.0 ± 48.5	117.0 ± 19.4	52.7 ± 8.0	45.0 ± 15.7	11.7 ± 1.9
Control	171.7 ± 12.8	152.3 ± 30.2	118.0 ± 17.1	108.3 ± 14.2	35.3 ± 5.7
Gibson Island					
Treatment	113.3 ± 31.2	132.7 ± 34.8	61.3 ± 10.7	16.0 ± 3.6	6.0 ± 1.5
Control	78.0 ± 24.1	68.3 ± 16.5	102.0 ± 18.9	40.3 ± 3.5	20.7 ± 2.4
A. americanum					
BARC					
Treatment	2.3 ± 1.9	1.0 ± 1.0	0.7 ± 0.3	0.3 ± 0.3	0.3 ± 0.3
Control	15.3 ± 4.2	40.0 ± 9.5	108.0 ± 3.0	72.0 ± 17.8	49.7 ± 6.9
Gibson Island					
Treatment	108.3 ± 19.4	126.7 ± 31.9	58.0 ± 9.7	8.7 ± 3.2	1.0 ± 1.0
Control	45.7 ± 2.1	106.7 ± 31.0	219.7 ± 48.6	114.3 ± 20.4	92.3 ± 42.1

[a] Four sample dates at Loch Raven, three sample dates at the other two sites.

numbers of nymphs at the control areas were significantly greater ($P = 0.0047$, and 0.0003, respectively) than at the treatment area, the reverse of situation in 1998.

At Loch Raven, where control area nymphs outnumbered treatment nymphs at the start of the study, total number of nymphs captured in the treatment area expressed as a percentage of the total number of nymphs captured in the control area dropped from 73.6% in 1998 to 22.8% in 2002 (Table 2) in spite of a decrease in control numbers in 2002 (Table 3). Actual numbers of *I. scapularis* nymphs declined by 81.3, 94.7 and 94.9% at the treatment areas

Table 2. Numbers of host-seeking nymphs captured by flagging at each treatment site expressed as percent of the numbers or nymphs captured at respective paired control area[a]

	%				
	1998[b]	1999	2000	2001	2002
I. scapularis					
Loch Raven	74	44	22	21	23
BARC	138	77	45	41	33
Gibson Island	146	194	60	40	29
A. americanum					
BARC	15	3	1	<1	1
Gibson Island	237	119	26	8	1

[a] Decreasing percentages for a location over time indicate that numbers of nymphs at its treatment area declined, whereas numbers of nymphs at the paired control area did not experience such a decline.
[b] Pretreatment.

Table 3. Percent mortalities[a] of *I. scapularis* nymphs due to '4-poster' treatments at three study sites

	% mortality			
	1998–2000[b]	1999–2001	2000–2002	1998–2002
Loch Raven	70.6	52.0	None[c]	69.0
BARC	67.4	45.9	25.8	75.8
Gibson Island	58.6	79.6	51.8	80.0

[a] Mortalities calculated according to Henderson and Tilton (1955).
[b] Percent mortality based on change from nymphs of parental or grandparental generation (two or four years previous).
[c] Numbers of nymphs in control area declined 41.6% during this period, whereas the decline in the treated population was 25.6% for same period.

at Loch Raven, Gibson Island and BARC, respectively from 1998 to 2002. However, the precipitous decline (29.4–79.4%) in *I. scapularis* nymphal numbers at the treatment and control areas of all sites in 2002 resulted in lower values for percent control than actual percent decline.

Henderson and Tilton (1955) percent mortality calculations, which take into account natural population changes, as manifested in this study in numbers of nymphs in the corresponding control areas, indicated that mortality attributable the effects of the '4-posters' over the period from 1998 to 2002 was 69.0% at Loch Raven, 75.8% at BARC, and 80.0% at Gibson Island. In the case of *I. scapularis* with its two-year life cycle, the Henderson–Tilton formula is most appropriately applied to populations at two-year intervals (odd years with odd years, even years with even years) (Table 3).

At Gibson Island and BARC, where both species coexist, *A. americanum* experienced much steeper declines in treatment areas than did *I. scapularis*. From 1998 to 2002 numbers of *A. americanum* nymphs decreased 99.1% on Gibson Island and 87% at BARC, whereas by 2002 numbers of nymphs at their respective control areas had increased by 2–3 times from 1998 numbers. Control of *A. americanum* at Gibson Island was 99.5 and 95.3% at BARC.

Discussion

The impact of the '4-poster' devices on the populations of *I. scapularis*, as manifested in changes of numbers of nymphs captured by flagging, was obvious by 2000. Because of the two-year life cycle of *I. scapularis*, the effects of an intervention against the cohort of adults that became active in the fall of 1998 would be expected to be evident in nymphal populations in 2000. The sudden large drop in numbers at the treatment areas in 2000 from the levels of the two previous years was not seen in the control areas, and was perhaps the most obvious indicator of the impact of the '4-poster' on the *I. scapularis* populations. A decline in *I. scapularis* nymphal numbers in all treatment areas during 1999 may, in the cases of BARC and Gibson Island, have been due to some larvae being killed in the summer when the devices were operated against *A. americanum* larvae and nymphs.

The substantial decline (>40% from previous years at control sites) in nymphal populations at all treatment and control areas in 2002, masked the effects of the '4-poster' intervention against *I. scapularis*. Numbers of blacklegged ticks already low in treatment areas in 2000 and 2001, particularly at BARC and Gibson Island, could not fall much lower than the 2002 averages of 12 and six nymphs total per date for all 15 locations. The summer of 1999 was characterized by an extreme drought, and the autumns of 2000 and 2001 were also unusually dry. Jones and Kitron (2000) related reduced numbers of

I. scapularis larvae to drought conditions the previous summer. The nymphs of 2002 had been unfed larvae in 2001, and the summer of 2000 was not dry. Survival of nymphs in mesh packets in the leaf litter at the Loch Raven and BARC control areas was much lower during the wet summer of 2000 than during the very dry summer of 1999 (Carroll 2003).

An even greater level of control might have been achieved, had the devices been operated during January and February. Host-seeking adult *I. scapularis* are active at temperatures as low as 4–5°C (Duffy and Campbell, 1994; Clark, 1995). Substantial numbers of *I. scapularis* were captured by flagging on warm winter days in Maryland (Carroll and Kramer, in press). During January and February (particularly the latter two week) in Maryland, enough days occur whose maximum and even average temperatures exceed the activity threshold of adult *I. scapularis*, that the continued operation of '4-posters' (at least on an ad hoc basis) during these months should be given serious consideration (Carroll and Kramer, in press).

The '4-poster' technology appears to have been highly effective against *A. americanum*. At Gibson Island the population was reduced to $<1\%$ of its 1998 level, whereas at the paired control area the numbers of *A. americanum* rose. At BARC, although the *A. americanum* population was small, nymphs declined by 87% compared to a three-fold increase at the control area. The high level of control of both species of ticks attests to the large percentage of these ticks using white-tailed deer as hosts at some point in their development. The apparently somewhat greater effectiveness of the '4-posters' against *A. americanum* than *I. scapularis* may be attributable to the targeting of a large percentage of all three parasitic stages of the former species.

In summary, the effectiveness of the '4-poster' demonstrated in this study indicates that it could be a valuable tool in suppressing populations of *I. scapularis* and *A. americanum*.

References

Bloemer, S.R., Zimmerman, R.H. and Fairbanks, K. 1988. Abundance, attachment sites, and density estimators of lone star ticks (Acari: Ixodidae) infesting white-tailed deer. J. Med. Entomol. 25: 295–300.

Carroll, J.F. 2003. Survival of larvae and nymphs of *Ixodes scapularis* Say (Acari: Ixodidae) in four habitats in Maryland. P. Entomol. Soc. Wash. 105: 120–126.

Carroll, J.F. and Kramer, M. Winter activity of *Ixodes scapularis* (Acari: Ixodidae) and the operation of deer-targeted tick control devices in Maryland. J. Med. Entomol (in press).

Clark, D.D. 1995. Lower temperature limits for activity of several ixodid ticks (Acari: Ixodidae): effects of body size and temperature change. J. Med. Entomol. 32: 449–452.

Duffy, D.C. and Campbell, S.R. 1994. Ambient air temperature as a predictor of activity of adult *Ixodes scapularis* (Acari: Ixodidae). J. Med. Entomol. 31: 178–180.

Duncan, I.M. and Monks, N. 1992. Tick control on eland (*Taurotragus oryx*) and buffalo (*Syncerus caffer*) with flumethrin 1% pour-on through a Duncan applicator. J. S. Afr. Vet. Assoc. 63: 7–10.

Fish, D. and Dowler, R. 1989. Host associations of ticks (Acari: Ixodidae) parasitizing medium sized mammals in a Lyme disease endemic area of southern New York. J. Med. Entomol. 26: 200–209.

Henderson, C.F. and Tilton, E.W. 1955. Tests with acaricides against the white flour mite. J. Econ. Entomol. 48: 157–161.

Jones, C.J. and Kitron, U.D. 2000. Populations of *Ixodes scapularis* (Acari: Ixodidae) are modulated by drought at a Lyme disease focus in Illinois. J. Med. Entomol. 37: 408–415.

Liegner, K.B. 1991. Acaricide dispenser. US Patent # 5,050, 539 dated 24 September 1991.

Marchinton, R.L. and Hirth, D.H. 1984. Behavior. In: White-tailed Deer: Ecology and Management, L.K. Haile (ed.), pp. 129–168. Stackpole Books, Harrisburg, PA.

Pound, J.M., Miller, J.A., George, J.E. and LeMeilleur, C.A. 2000a. The '4-poster' passive topical treatment device to apply acaricide for controlling ticks (Acari: Ixodidae) feeding on white-tailed deer. J. Med. Entomol. 37: 588–594.

Pound, J.M., Miller, J.A. and George, J.E. 2000b. Efficacy of amitraz applied to white-tailed deer by the '4-poster' topical treatment device in controlling free-living lone star ticks (Acari: Ixodidae). J. Med. Entomol. 37: 878–884.

Schmidtmann, E.T., Carroll, J.F. and Watson, D.W. 1998. Attachment-site patterns of black-legged ticks (Acari: Ixodidae) on white-tailed deer and horses. J. Med. Entomol. 35: 59–63.

Sonenshine, D.E., Allen, S.A., Norval, R.A.I. and Burridge, M.J. 1996. A self-medicating applicator for control of ticks on deer. Med. Vet. Entomol. 10: 149–154.

Watson, T.G. and Anderson, R.C. 1976. *Ixodes scapularis* Say on white-tailed deer (*Odocoileus virginianus*) from Long Point, Ontario. J. Wildlife Dis. 12: 66–71.

Wilson, M.L., Adler, G.H. and Spielman, A. 1985. Correlation between abundance of deer and that of the deer tick, *Ixodes dammini* (Acari: Ixodidae). Ann. Entomol. Soc. Am. 78: 172–176.

Wilson, M.L., Telford III, S.R., Piesman, J. and Spielman, A. 1988. Reduced abundance of *Ixodes dammini* (Acari: Ixodidae) following elimination of deer. J. Med. Entomol. 25: 224–228.